

**EEE 498/591: Introduction to Quantum Information and Quantum Computing**

**Instructor:** Dr. Christian Arenz

[Christian.Arenz@asu.edu](mailto:Christian.Arenz@asu.edu)

**Course Description:**

Quantum computers promise to offer remarkable computational advantages for a range of problems, by utilizing properties that are unique to quantum-mechanical systems, such as atoms and photons. The goals of this course are to establish an understanding of how quantum computers operate and where these computational advantages come from, and to give an overview of the current state-of-the-art of the field.

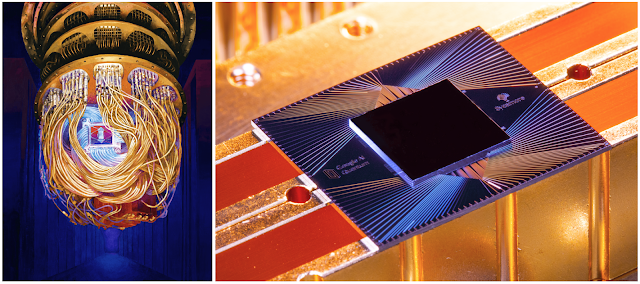


Figure : Google’s Sycamore quantum processor, image taken from <https://ai.googleblog.com/2019/10/quantum-supremacy-using-programmable.html>

We will begin by reviewing the mathematical tools relevant for formulating the theory of quantum computation, followed by an overview of fundamental concepts such as qubits, quantum logic gates, and quantum algorithms. Afterwards, physical platforms for quantum computation will be reviewed, which will include discussions of the capabilities of current quantum computing devices, as shown in Figure 1. Finally, we will explore the technological challenges that must be overcome in order to realize the full power that quantum computers have to offer.

Learning progress will be assessed through homework assignments, a midterm exam, a final exam, and a final project. In the project, students will have the opportunity to dive deeper into a chosen subject area (for example, simulations of quantum algorithms, implementations of cloud-based quantum computing, etc). Students from all disciplines are welcome. A background in linear algebra will be required for the course. Familiarity with quantum mechanics and concepts from computer science will be helpful, but is not required.

**Syllabus:**

* Topics covered
  + Review: linear algebra, quantum mechanics, and models of computation
  + Quantum bits (qubits)
  + Quantum logic gates and quantum circuits
  + Quantum algorithms
  + How to build a quantum computer: physical platforms and implementations
  + Quantum computing in today’s noisy, intermediate-scale quantum (NISQ) era
  + Quantum computing challenges
* Learning outcomes

At the completion of the course, students will:

* + understand what makes quantum computers more powerful than classical computers in certain settings
  + be familiar with fundamental concepts of quantum computing, such as qubits, quantum logic gates, and quantum algorithms
  + be able to reason about quantum algorithms
  + be familiar with physical platforms used for quantum computation
  + understand the capabilities of quantum devices that are currently available
  + be familiar with current NISQ algorithms
  + be able to identify technological challenges to fully leverage the power of quantum computation
* Grading weight
  + Homework 20%, Project 30%, Midterm and final exam each 25%
* Prerequisites
  + Undergraduate linear algebra
  + Some background in quantum mechanics and computer science is certainly helpful, though not required to follow the class
* Textbooks and References
  + M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information,* Cambridge University Press (2010)
  + N. D. Mermin, *Quantum Computer Science: An Introduction*, Cambridge University Press (2007)
  + J. D. Hidary, *Quantum Computing: An applied Approach,* Springer (2019)
  + S. Aaronson, *Quantum Computing Since Democritus,* Cambridge University Press (2013)
  + <https://qiskit.org>
  + M. Cerezo et al., *Variational quantum algorithms,* [Nature Reviews Physics 3, 625-644 (2021)](https://www.nature.com/articles/s42254-021-00348-9)